

Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches

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Acknowledgments

State Working Group Members

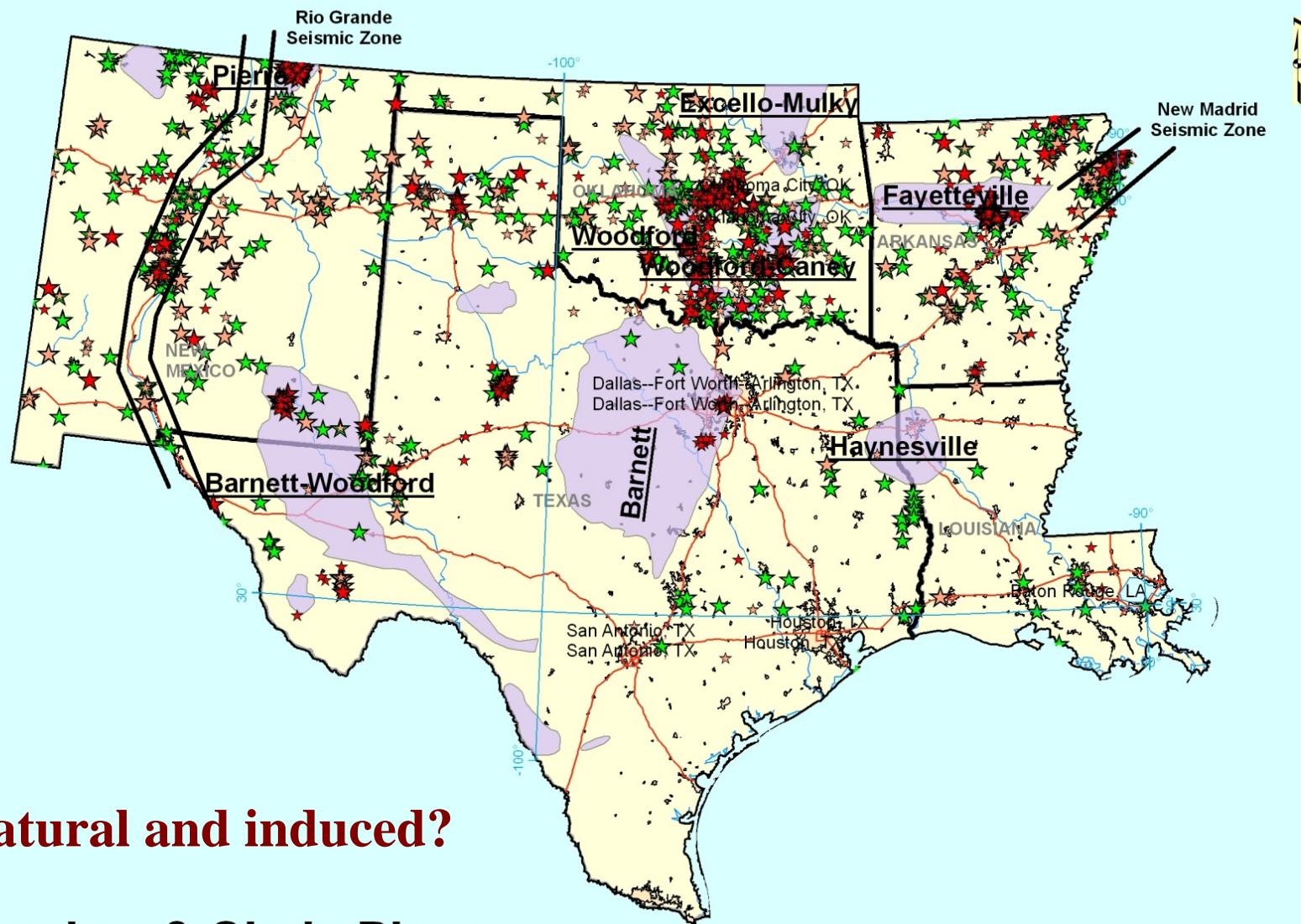
- Lawrence Bengal, Arkansas Oil and Gas Commission
- Douglas Johnson, Railroad Commission of Texas, retired
- Charles Lord, Oklahoma Corporation Commission
- James A Peterson, West Virginia Department of Environmental Protection
- Tom Tomastik ,Ohio Department of Natural Resources, retired
- Chuck Lowe, Ohio EPA
- Jim Milne, Colorado Oil and Gas Conservation Commission
- Denise Onyskiw, Colorado Oil and Gas Conservation Commission, retired
- Vince Matthews, Colorado Geologic Survey, retired

Expert Review Panel

- Brian Stump, Southern Methodist University
- Chris Hayward, Southern Methodist University
- Scott Ausbrooks, Arkansas Geological Survey
- Steve Horton, Center for Earthquake Research and Information, U of Memphis
- Ernest Majer, Lawrence Berkeley National Laboratory
- Norman Warpinski, Pinnacle
- John Satterfield, formerly with Chesapeake Energy
- Cliff Frohlich, Bureau of Economic Geology, University of Texas
- David Dillon, National Academy of Science
- Shah Kabir, Hess Energy
- Bill Smith, National Academy of Science, retired
- Roy Van Arsdale, University of Memphis
- Justin Rubenstein, USGS

Final Peer Review Panel

- Jeff Bull, Chesapeake Energy Corporation
- Robin McGuire, Lettis Consultants International, Inc.
- Craig Nicholson, University of California, Santa Barbara
- Kris Nygaard, ExxonMobil
- Heather Savage, Lamont-Doherty Earth Observatory, Columbia University
- Ed Steele, Swift Worldwide Services



Natural and induced?

Earthquakes & Shale Plays

0 45 90 180 270 360 Miles

Legend

≥ 2000	1973-1999	1699-1773	
Magnitude	Magnitude	Magnitude	
★ 0.0 - 3.0	★ 0.0 - 3.0	★ 0.0 - 3.0	Urban Areas
★ 3.1 - 5.0	★ 3.1 - 5.7	★ 3.1 - 5.7	Shale Gas Plays: EIA

Albers Projection
Central Meridian: -96
1st Std Parallel: 20
2nd Std Parallel: 60
Latitude of Origin: 40

United States Environmental Protection Agency

Region 6

GROUNDWATER CENTER

Covering Arkansas, Louisiana
New Mexico, Oklahoma & Texas

Presentation Summary

- Overview of Study Approach
- Discussion of engineering tools
- Summary of findings and recommendations

Overview of Study Approach

- Timeframe for effort
 - Earthquakes updated through 9/30/13.
 - References updated as of 5/23/14.

Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- Development of decision model
- Fundamentals of induced seismicity
- Explore petroleum engineering methods

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Overview of Study Approach

- Literature review and compilation
 - Peer reviewed material only
 - Comprehensive, but moving target

Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
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Overview of Study Approach

- Analysis of four case examples
 - Central Arkansas Area
 - North Texas Area
 - Braxton County, West Virginia
 - Youngstown, Ohio

Overview of Study Approach

- Analysis of four case examples
 - Geologic site summary
 - History of seismicity
 - State actions
 - Application of reservoir engineering methods
 - Lessons learned

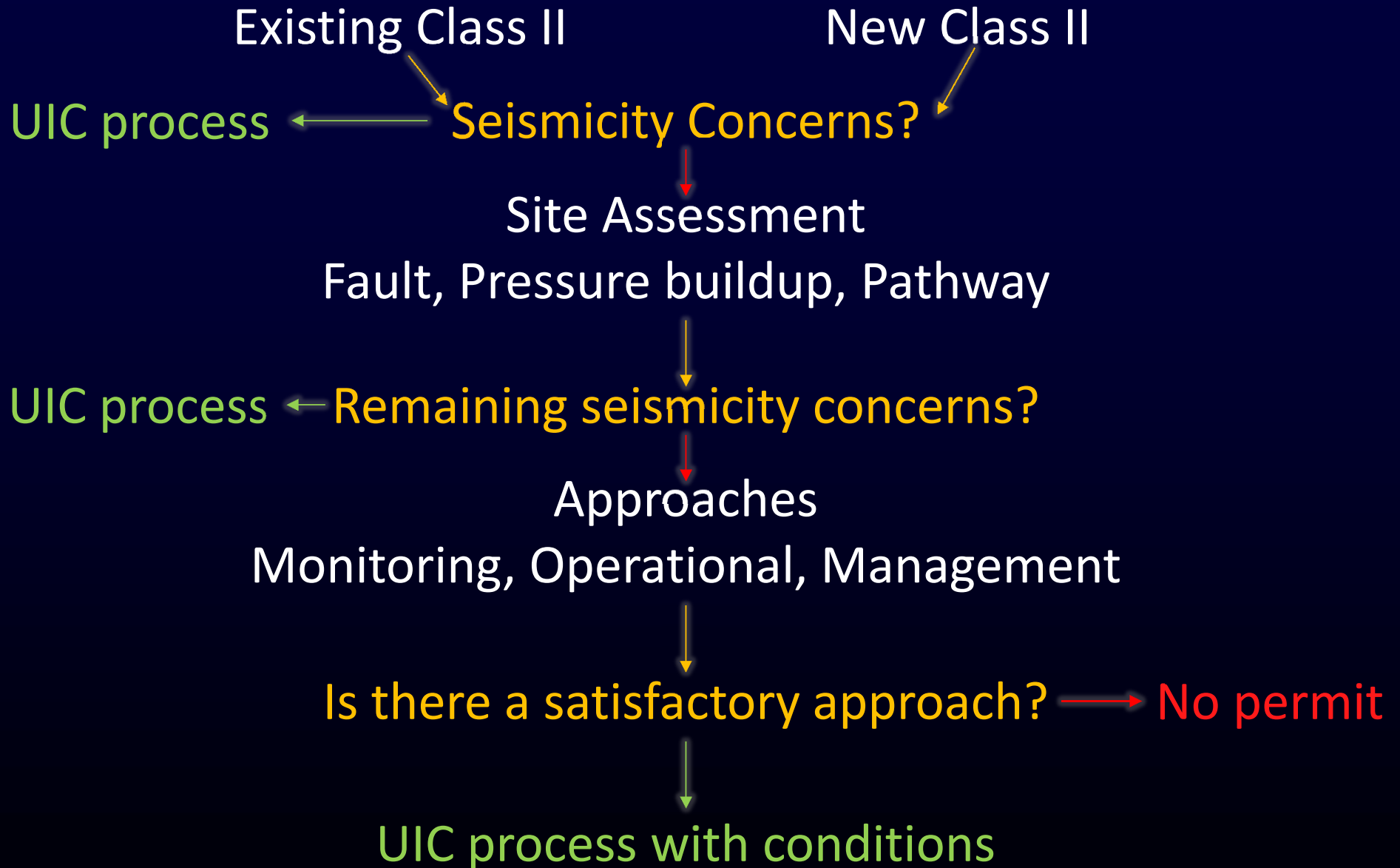
Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- **Development of decision model**
- Fundamentals of induced seismicity
- Explore petroleum engineering methods

Overview of Study Approach

- Development of decision model
 - Received much input throughout process
 - Comprehensive thought process - not specific
 - Founded on Director Discretionary Authority

DECISION MODEL FOR UIC DIRECTORS



Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- Development of decision model
- **Fundamentals of induced seismicity**
- Explore petroleum engineering methods

Overview of Study Approach

- Fundamentals of induced seismicity
 - Captures a broader potential audience
 - Provides a general reference
 - Includes geoscience and engineering aspects

Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- Development of decision model
- Fundamentals of induced seismicity
- Explore petroleum engineering methods

Overview of Study Approach

- Explore petroleum engineering methods
 - Data obtained from suspected wells in case examples were analyzed.
 - Two fundamental approaches were used.
 - Falloff testing.
 - Operational data analysis.

Presentation Summary

- Overview of Study Approach
- Discussion of engineering tools
- Summary findings and recommendations

Discussion of Engineering Tools

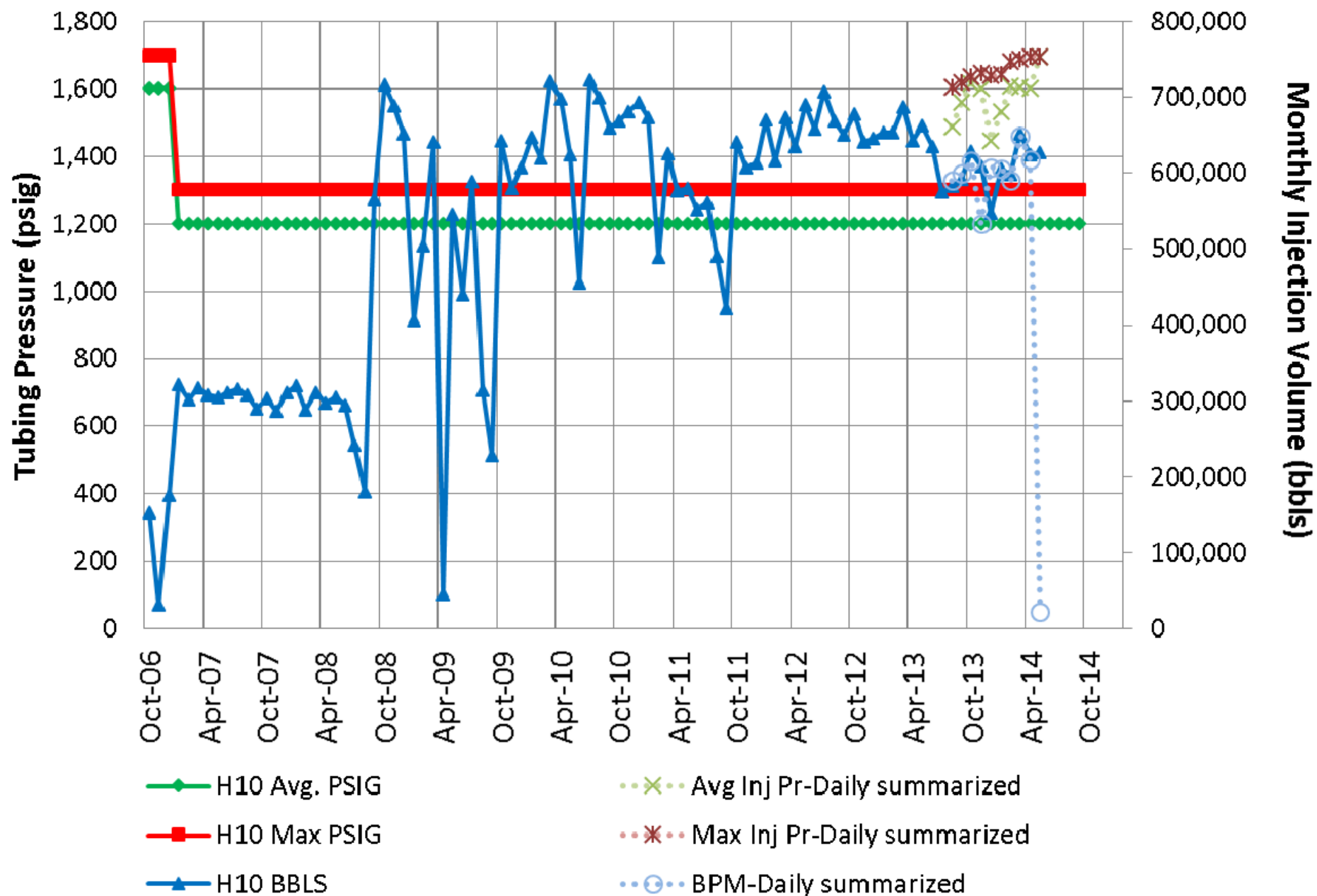
- A few points.
 - Quality of data is crucial.
 - These methods are an interpretive tool, not a fix-all.
 - PE tools can determine if fracture flow is predominant.
 - Fractured reservoirs can transmit pressure buildup over great distances.
 - PE tools can detect reservoir changes at distance, including faults.
 - Correspondence between well behavior and seismicity was apparent in some case example wells.

Discussion of Engineering Tools

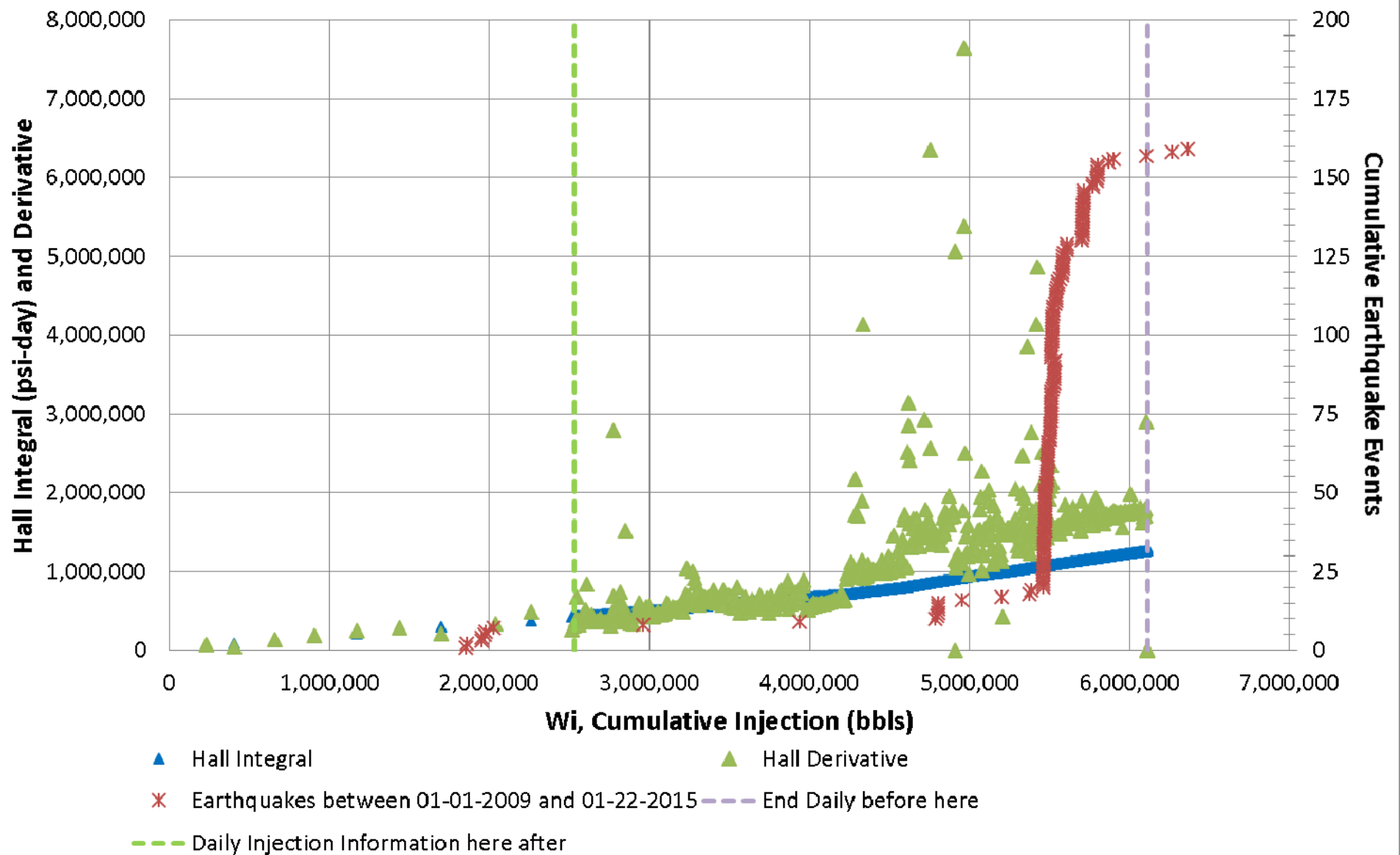
- Two fundamental approaches
 - Well testing
 - Pressure transient or falloff testing can determine if a reservoir is fractured, as well as static formation pressure.
 - Function of near well conditions.
 - Analysis of operational data
 - Hall plots using operational data (rates and pressures) indicate changes in transmissivity (ease of injection) at distance.
 - Covers both near wellbore and distance increasing with time.

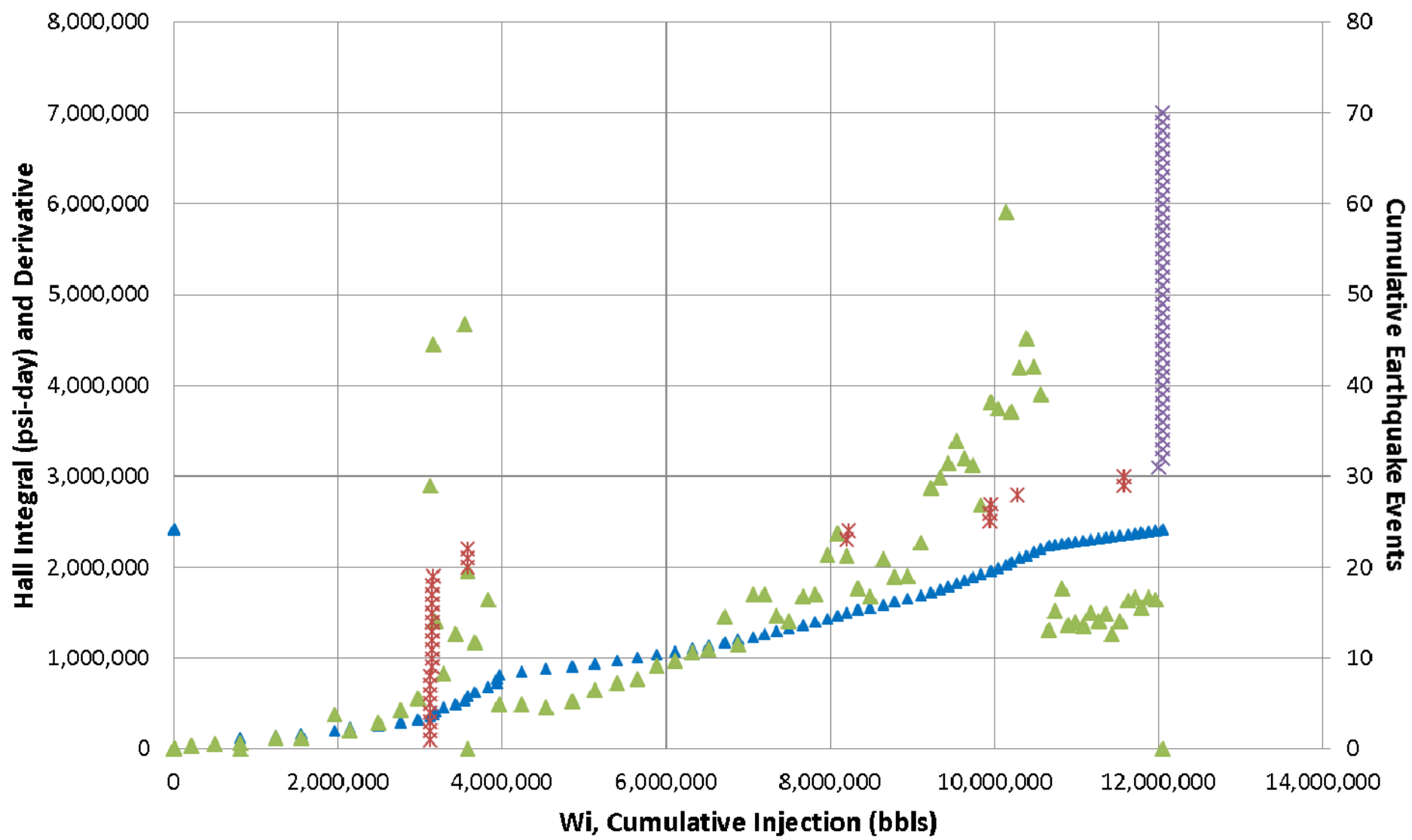
Discussion of Engineering Tools

- Examples – operational data



Constant disposal or tubing pressures are probably not measured data.





Presentation Summary

- Overview of Study Approach
- Aspects of engineering tools
- Summary of findings and recommendations

Summary of Findings and Recommendations

- Take a proactive approach
 - Realistic analysis instead of definitive proof
 - Monitor seismicity trends in regional area
 - Engage operators early
 - Additional site geologic data
 - Voluntary actions
 - Increased operational data
 - Engage external expertise if warranted
 - Modify operations if warranted

Summary of Findings and Recommendations

- Perform multi-disciplinary characterization of site. (injection reservoir testing, analysis, consultation, literature).
- Case examples – deep fractured reservoirs
 - Fractures more likely to communicate pressure buildup long distances
 - Buildup can be directional and extend miles
 - Fractured reservoirs can result in communication with basement rocks, lower confining strata is important.

Summary of Findings and Recommendations

- Assure high quality operational data
- Permitting contingencies (green, yellow, red lights) are an excellent tool to address site uncertainties
- Increased seismometers better define seismic activity.

Final Words

- EPA Region 6 is preparing a seismicity training module for injection well regulators.
- We have a summary poster set up.

